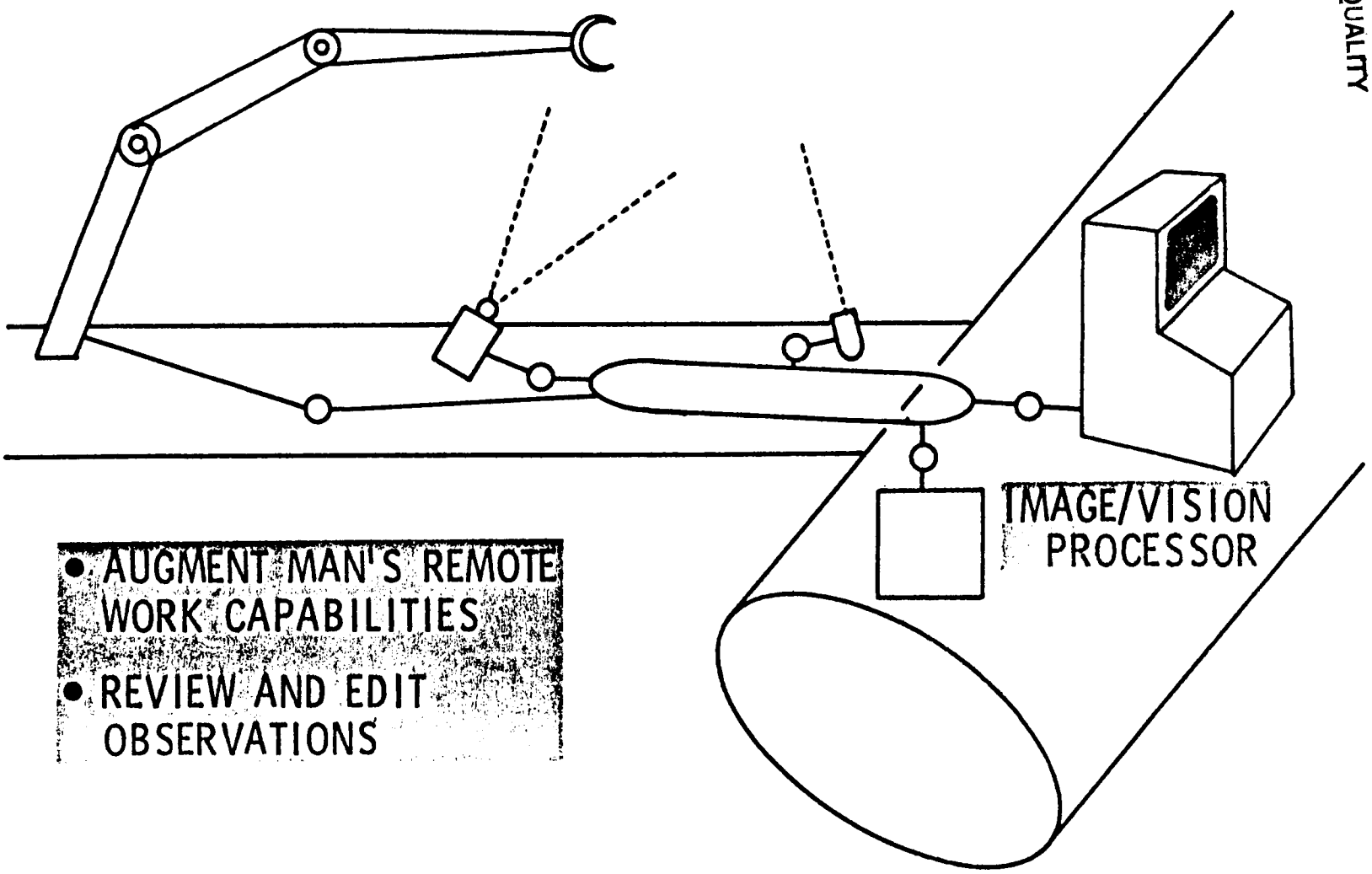
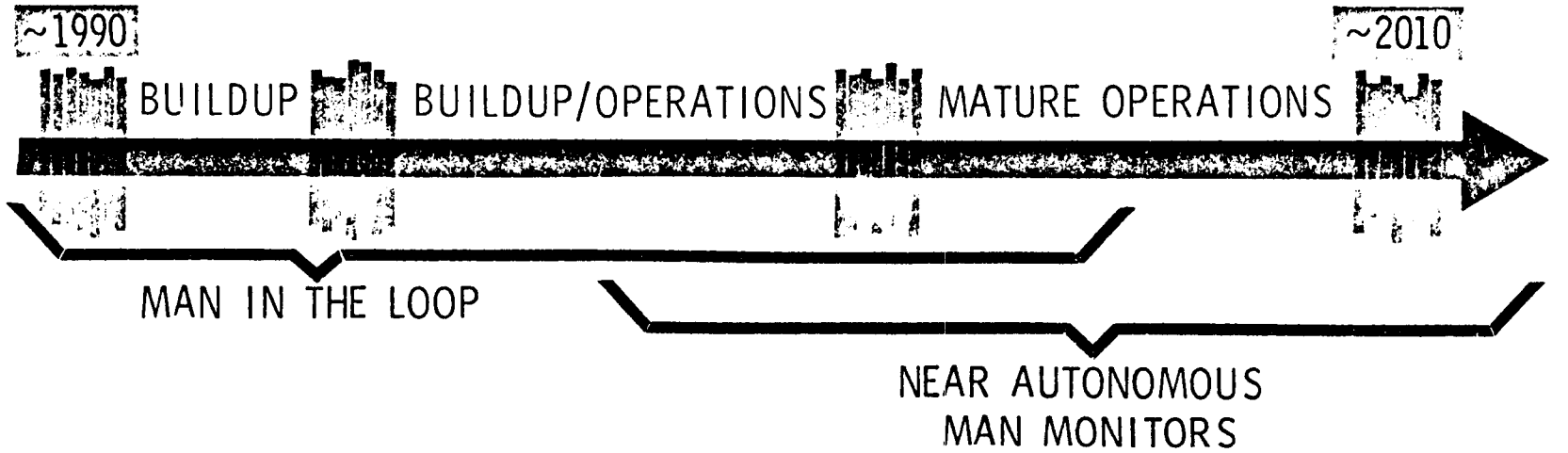
SPACE STATION WILL HAVE REQUIREMENTS FOR CONDUCTING SUCH MANIPULATION/OBSERVATION ACTIVITIES AS CONSTRUCTION, MAINTENANCE, MANUFACTURING, EXPERIMENTS, RENDEZVOUS AND DOCKING, POINTING AND TRACKING, TARGET ACQUISITION/IDENTIFICATION, AND SOLAR SYSTEM OBSERVATIONS. INITIALLY, MOST OF THESE MANIPULATIONS/OBSERVATIONS WILL REQUIRE A MAN-IN-THE-LOOP WITH VIDEO DISPLAY, WHICH IN TURN WILL REQUIRE REAL-TIME PROCESSING OF DATA AND INFORMATION FOR VISUAL PRESENTATION WILL IMPROVE MAN'S OPERATIONAL CAPABILITIES. AS THE SPACE STATION MATURES, SOME OF THESE OPERATIONS WILL BECOME NEARLY AUTONOMOUS WITH MAN MONITORING, WHICH WILL CREATE AN ADDITIONAL NEED FOR REAL-TIME PROCESSING AT DATA RATES EXCEEDING 100 MBITS/SEC. PROCESSING AT SUCH HIGH RATES WILL MOST LIKELY BE ACCOMPLISHED BY SPECIAL PURPOSE COMPUTING IMPLEMENTING COMPUTATIONALLY SIMPLE ALGORITHMS. CURRENT TECHNOLOGY PROJECTIONS INDICATE THE LACK OF AVAILABILITY OF SUCH SPECIAL PURPOSE COMPUTING IN THE EARLY 1990s, AND NASA NEEDS TO ACCELERATE THIS TECHNOLOGY FOR APPLICATION TO SPACE STATION. POTENTIAL FUNCTIONS FOR VIDEO IMAGE SPECIAL PURPOSE PROCESSING ARE BEING INVESTIGATED, SUCH AS SMOOTHING, ENHANCEMENT, RESTORATION AND FILTERING, DATA COMPRESSION, FEATURE EXTRACTION, OBJECT DETECTION AND IDENTIFICATION, PIXEL INTERPOLATION/EXTRAPOLATION, SPECTRAL ESTIMATION AND FACTORIZATION, AND VISION SYNTHESIS. ALSO, ARCHITECTURAL APPROACHES ARE BEING IDENTIFIED AND A CONCEPTUAL DESIGN GENERATED. COMPUTATIONALLY SIMPLE ALGORITHMS WILL BE RESEARCHED AND THEIR IMAGE/VISION EFFECTIVENESS DETERMINED. SUITABLE ALGORITHMS WILL BE IMPLEMENTED INTO AN OVERALL ARCHITECTURAL APPROACH THAT WILL PROVIDE IMAGE/VISION PROCESSING AT VIDEO RATES THAT ARE FLEXIBLE, SELECTABLE, AND PROGRAMMABLE.

IMAGE/VISION PROCESSOR



- AUGMENT MAN'S REMOTE WORK CAPABILITIES
- REVIEW AND EDIT OBSERVATIONS

SPACE STATION EVOLUTION



MANIPULATIONS

- CONSTRUCTION
- MAINTENANCE
- MANUFACTURING
- EXPERIMENTS
- RENDEZVOUS AND DOCKING

OBSERVATIONS

- EARTH/SOLAR SYSTEM/DEEP SPACE
- MANUFACTURING
- EXPERIMENTS
- POINTING AND TRACKING
- TARGET ACQUISITION/IDENTIFICATION

SPACE STATION ACTIVITIES NEEDING VIDEO

- CONSTRUCTION
- SATELLITE SERVICING
- RENDEZVOUS
- PROXIMITY OPERATIONS
- COMMUNICATION AND TRACKING
- INSPECTION
- MAINTENANCE
- PAYLOAD DELIVERY/RETRIEVAL
- EXPERIMENT MONITORING
- DATA MANAGEMENT
- TRAINING

EXAMPLE SPACE STATION APPLICATIONS OF VIDEO IMAGE PROCESSING

RENDEZVOUS

- TARGET IDENTIFICATION
- TARGET TRACKING FOR CROSS RANGE VELOCITY AND POSITION ESTIMATION
- POINT TARGET DETECTION

PROXIMITY OPERATIONS

- TARGET TRACKING FOR TARGET ORIENTATION, POSITION AND VELOCITY ESTIMATION

DATA MANAGEMENT

- BANDWIDTH COMPRESSION FOR DATA MOVEMENT AND ARCHIVING

INSPECTION

- MACHINE VISION TECHNIQUES FOR VERIFICATION OF SPACE STATION STRUCTURAL INTEGRITY AND DETECTION AND CLASSIFICATION OF DEFECTS

COMMUNICATION AND TRACKING

- BANDWIDTH COMPRESSION FOR DOWNLINK TRANSMISSION
- MULTI-TARGET TRACKING FOR AREA TRAFFIC CONTROL
- TARGET DETECTION AND IDENTIFICATION FOR AREA TRAFFIC CONTROL

CONSTRUCTION

- VERIFICATION OF CONSTRUCTION STEPS

VIDEO IMAGE PROCESSOR

506-58-13/N. D. MURRAY

OBJECTIVE

- RESEARCH AND DEVELOP THE REAL-TIME DATA AND INFORMATION PROCESSING OF VIDEO IMAGE DATA FOR SPACE STATION REQUIREMENTS.

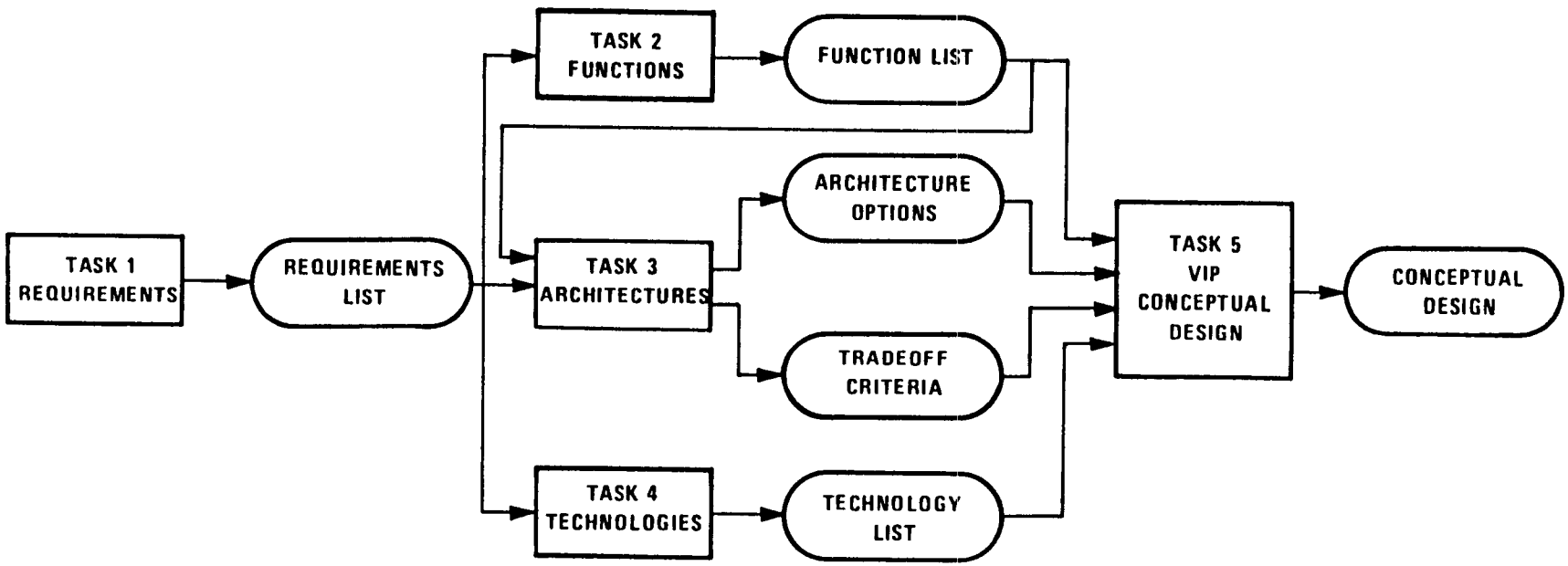
APPROACH

- INVESTIGATE POTENTIAL FUNCTIONS FOR VIDEO RATE IMAGE/VISION SPECIAL PURPOSE PROCESSING, IDENTIFY ARCHITECTURAL APPROACH, AND GENERATE A CONCEPTUAL DESIGN. HONEYWELL

- RESEARCH COMPUTATIONALLY SIMPLE ALGORITHMS AND DETERMINE THEIR IMAGE/VISION EFFECTIVENESS.

- IMPLEMENT SELECTED ALGORITHMS IN SPECIAL HARDWARE DESIGNS AND EVALUATE.

- USING RESULTS OF PROCEEDING EFFORTS, IMPLEMENT AN OVERALL ARCHITECTURAL DESIGN THAT WILL PROVIDE IMAGE/VISION PROCESSING AT VIDEO RATES THAT ARE FLEXIBLE, SELECTABLE AND PROGRAMMABLE.


TASK 1
REQUIREMENTS
REQUIREMENTS
LIST
TASK 2
FUNCTIONS
FUNCTION LIST
TASK 3
ARCHITECTURES
ARCHITECTURE
OPTIONS
TRADEOFF
CRITERIA
TASK 4
TECHNOLOGIES
TECHNOLOGY
LIST
TASK 5
VIP
CONCEPTUAL
DESIGN
CONCEPTUAL
DESIGN

VIDEO SOURCES

- CAMERAS

  INTERNAL

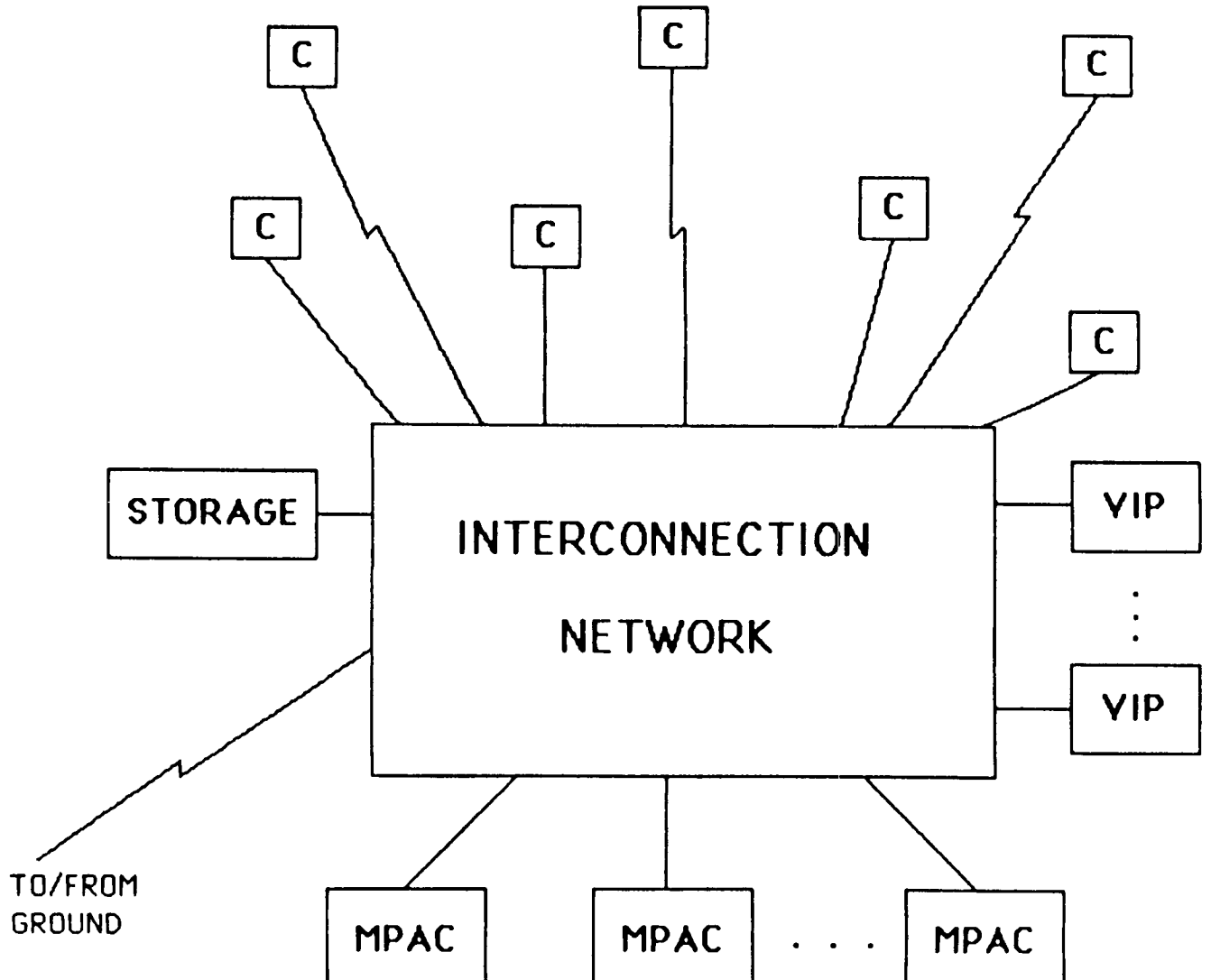
  - MODULE CAMERAS
  - EXPERIMENT MONITORING

  EXTERNAL
  - MRMS
  - DOCKING PORTS
  - LOCAL AREA TRAFFIC MONITORING
  - SERVICING FACILITY
  - ON MMUS
  - OMV/OTV
  - FREE FLIERS

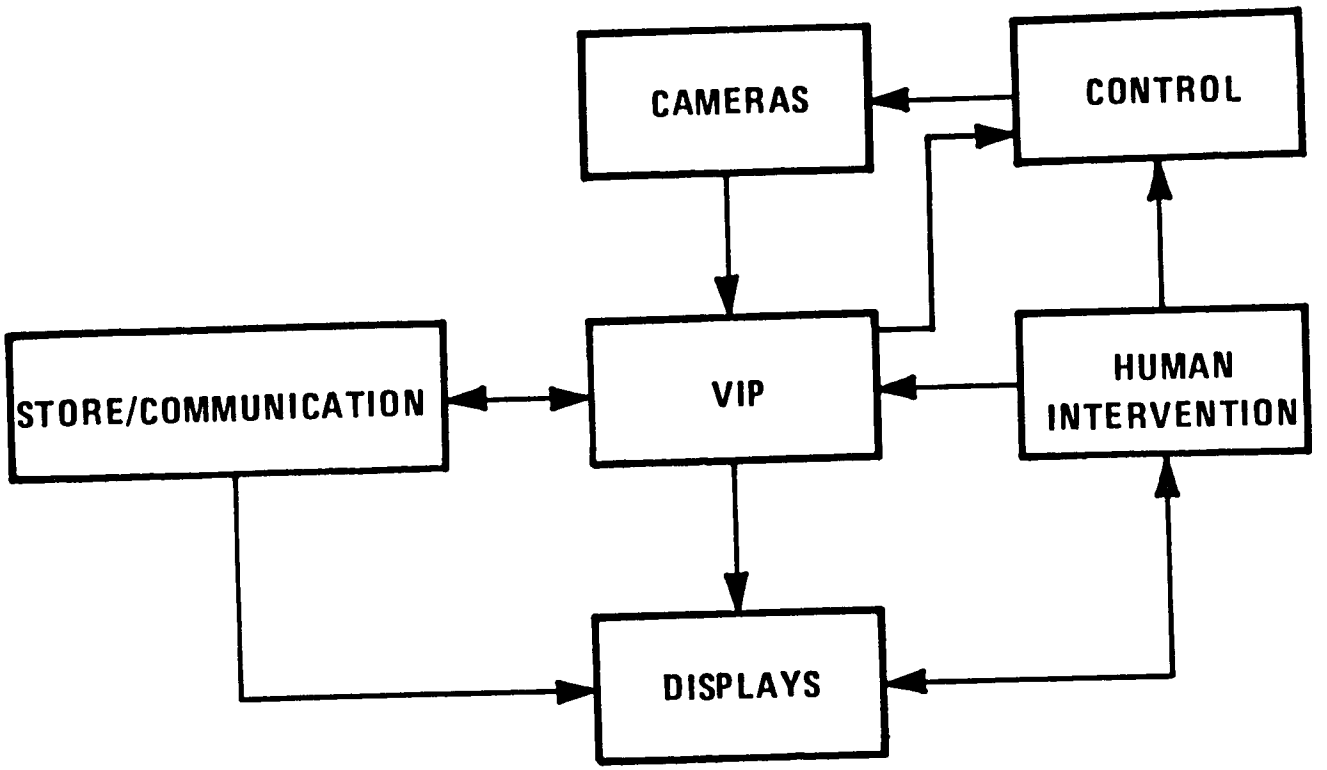
- VIDEO STORAGE DEVICES

- UPLINK VIDEO

VIDEO DISTRIBUTION

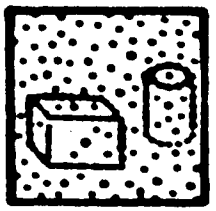


VIDEO IMAGE PROCESSING IN SPACE STATION

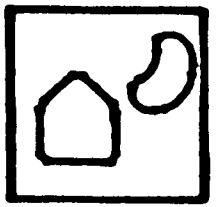


- REAL TIME, 100 MBPS

ALGORITHMS

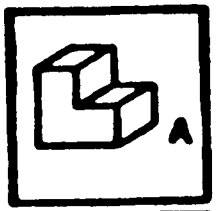


- **PROCESSING**
  - REMOVAL OF NOISE
  - HISTOGRAM
  - THRESHOLDING

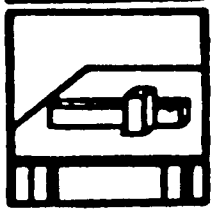


- **ANALYSIS**

STRUCTURAL	STATISTICAL
EDGES	DENSITY FUNCTION
VERTICES	MOMENTS
REGIONS	CO-OCCURENCE MATRICES



- **RECOGNITION**
  - OBJECTS
  - TEXTURES



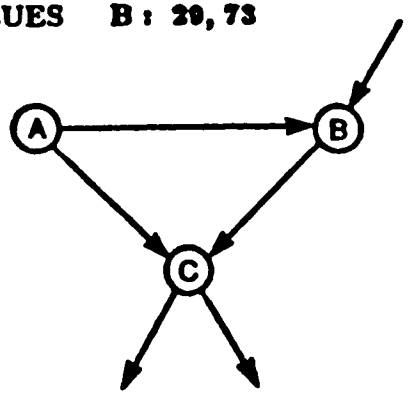
- **UNDERSTANDING**
  - SCENE DESCRIPTION
  - SPATIAL RELATIONSHIP
  - MOTION PARAMETERS

NATURE OF PROCESSING

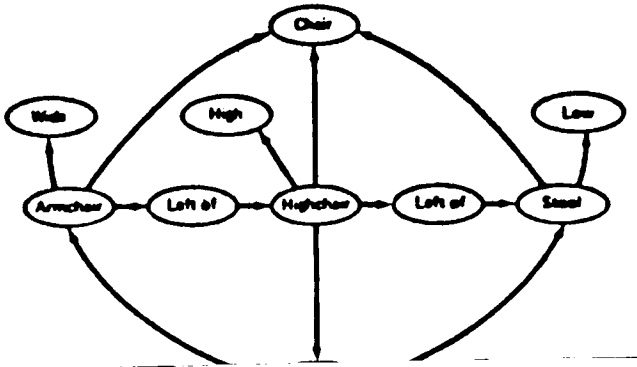
IMAGE:
ORDERED SETS OF NUMBERS — 32 64 41 49

IMAGE FEATURES:
SYMBOLS ASSOCIATED WITH NUMERICAL VALUES — A : 37, 26; B : 29, 73

OBJECTS:
INTERRELATED SYMBOLS (GRAPH)



SCENE:
SEMANTIC NETS



FUNCTIONAL ANALYSIS

GOAL: FUNCTIONAL DECOMPOSITION OF SPACE STATION TASKS AND DETERMINATION OF COMPUTATIONAL REQUIREMENTS

FEATURES:

- OPERATION THROUGHPUT
- DATA THROUGHPUT
- POTENTIAL PARALLELISM
- DATA DEPENDENT BEHAVIOR
- WORD SIZE REQUIREMENTS
- OPERATION DENSITY, (OPS/PIXEL OR OPS/FEATURE)
- IMPLICATIONS FOR
  - PROCESSING SUPPORT
  - COMMUNICATION REQUIREMENTS
  - CONTROL STRATEGIES

IMAGE ANALYSIS COMPUTATIONAL MODEL

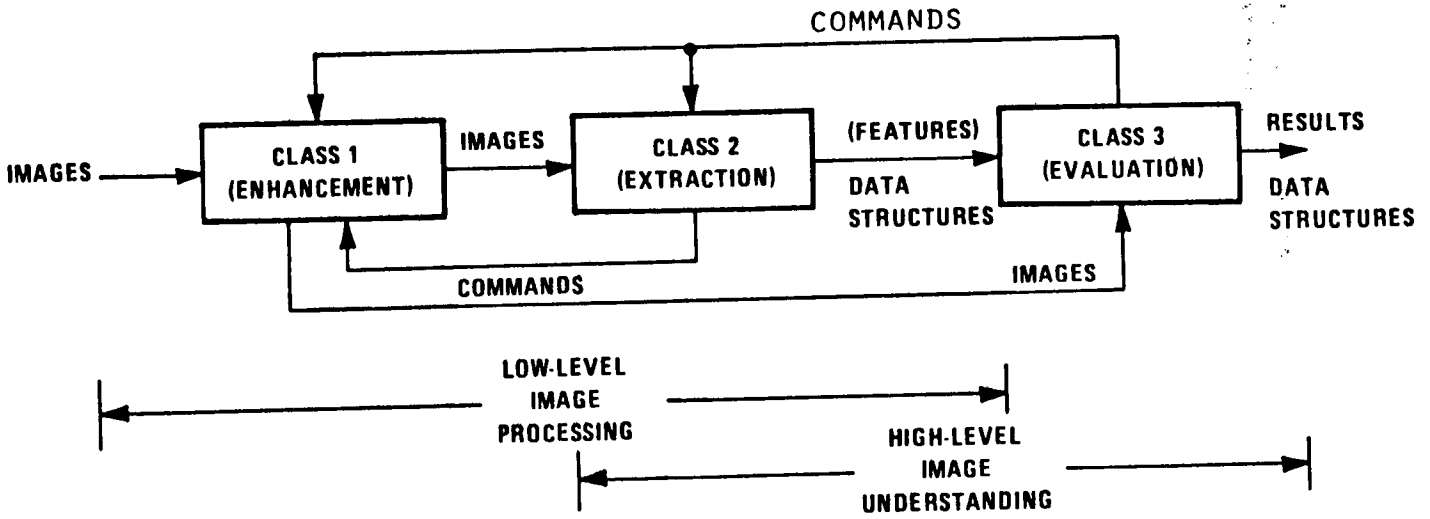


IMAGE PROCESSING ENVIRONMENT

PARALLEL TASKS MAY BE FORMULATED BY EXPLOITING PARALLELISM IN THE TRANSFORMATIONS OR DATA STRUCTURES

TRANSFORMATIONS MAY BE CLASSIFIED AS

- IMAGE TO IMAGE (PREPROCESSING)
- IMAGE TO DATA STRUCTURE (DATA REDUCTION)
- DATA STRUCTURE TO DATA STRUCTURE (HIGH LEVEL)

IMAGE-TO-IMAGE FUNCTIONS

EXAMPLE	MOPS
• DETECTOR COMPENSATION	8-9
• THRESHOLDING	8
• FILTERING	400
• CORRELATION	400
• EDGE DETECTION	400-800
• ENHANCEMENT	100
• CHANGE DETECTION	8

DATA ACCESS PATTERN

FIXED, HIGHLY PARALLEL

IMAGE-TO-IMAGE FUNCTIONS (CONTINUED)

- DATA DEPENDENCIES - VERY LOW
- WORD SIZE REQUIREMENTS - PIXEL RESOLUTION
- OPERATION DENSITY - $10\text{-}10^2$ OPS/PIXEL
- PROCESSING SUPPORT - SIMPLE ARITHMETIC OPERATIONS
- COMMUNICATION - FIXED, PREDETERMINED
- CONTROL STRATEGIES - SYNCHRONOUS, SIMD

IMAGE-TO-DATA STRUCTURE FUNCTIONS

EXAMPLES	MOPS	DATA ACCESS PATTERN
• REGION GROWING	20-30 (EMPIRICAL)	CONSTRAINED
• LINE AND SHAPE DETECTION (HOUGH TRANSFORM)	200-300	FIXED
• ENCODING VIA - QUAD TREES - RECTANGLE CODES	?	?
• STATISTICS	30	PREDETERMINED

IMAGE-TO-DATA STRUCTURE FUNCTIONS

(CONTINUED)

- DATA DEPENDENCIES - TENDS TO BE HIGH
- WORD SIZE REQUIREMENTS - 16 BITS
- OPERATION DENSITY - $10\text{-}10^3$ OPS/FEATURE
- PROCESSING SUPPORT - ARITHMETIC, SOME LOGICAL, LIMITED FLOATING POINT
- COMMUNICATION - CAN BE STRUCTURED IN A MANNER THAT CAN BE PREDETERMINED
- CONTROL STRATEGIES - INCLINED TOWARD MIMD

DATA STRUCTURE-TO-DATA STRUCTURE FUNCTIONS

EXAMPLES	MOPS	DATE ACCESS PATTERN
• MATCHING DESCRIPTIONS		
- GRAPHS	1-3	PREDETERMINED
- CONTOURS	20-30	PREDETERMINED
• MATCHING FEATURE VECTORS	1-2	FIXED
• 3-D STRUCTURE	?	UNKNOWN
• INFERENCE RULE EVALUATION	?	UNKNOWN
• POSITION ESTIMATION, TRACKING	?	UNKNOWN

DATA STRUCTURE-TO-DATA STRUCTURE FUNCTIONS (CONTINUED)

- DATA DEPENDENCIES - VERY HIGH
- WORD SIZE REQUIREMENTS - 32-64 BITS
- OPERATION DENSITY - 10^4-10^6 OPS/FEATURE
- PROCESSING SUPPORT - SYMBOLIC OPERATIONS, DATA MANIPULATION, NON-NUMERIC OPERATIONS
- COMMUNICATION - DYNAMIC, VARIABLE
- CONTROL STRATEGIES - MIMD

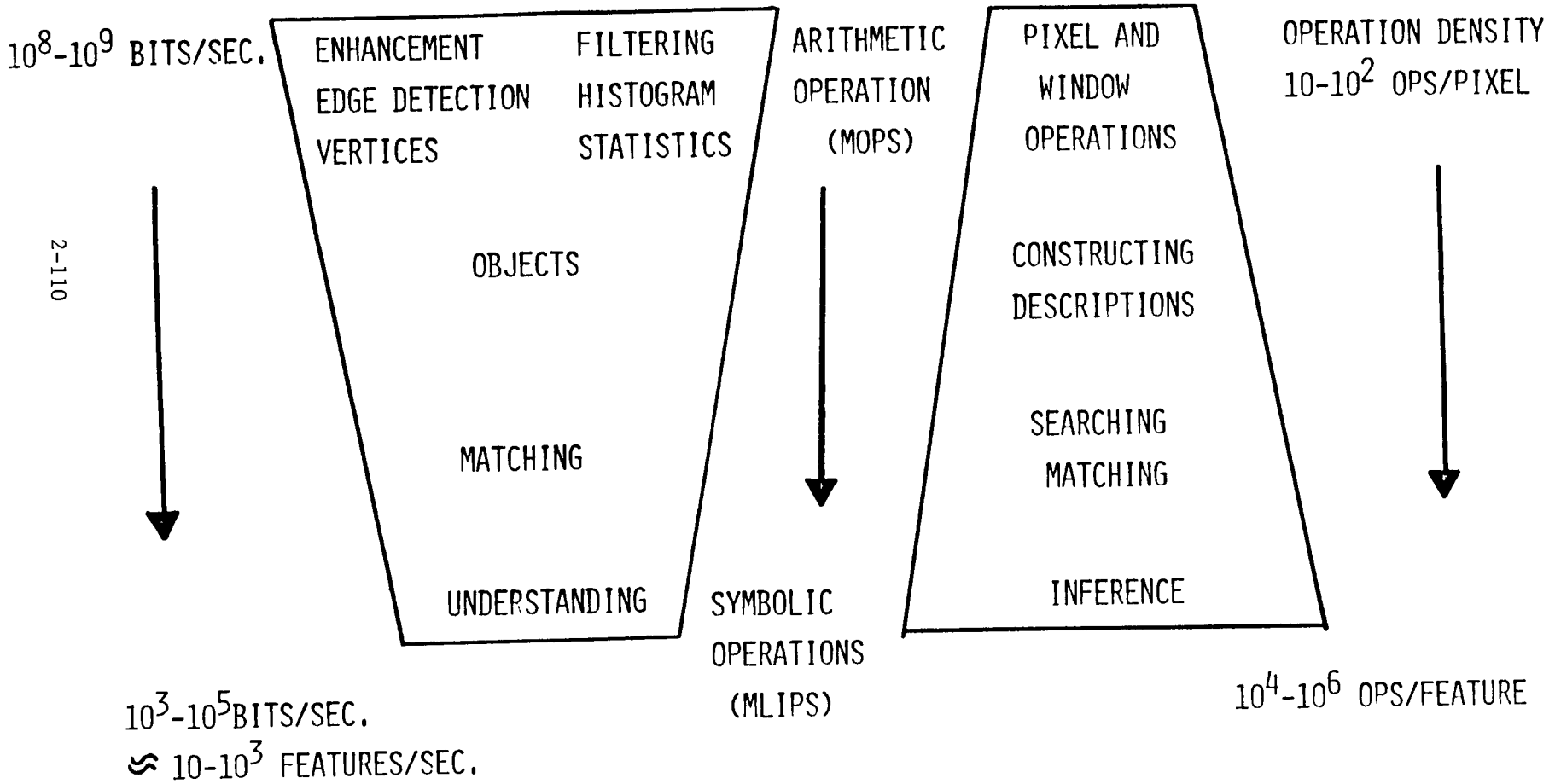
FUNCTIONAL ANALYSIS SUMMARY

	IMAGE TO IMAGE	IMAGE TO DATA STRUCTURE	DATA STRUCTURE TO DATA STRUCTURE
• DATA DEPENDENCIES	LOW	MEDIUM	HIGH
• ACCURACY	PIXEL RESOLUTION	16 BITS	32-64 BITS
• OPERATION DENSITY	$10\text{-}10^2$ OPS/PIXEL	$10\text{-}10^3$ OPS/FEATURE	$10^4\text{-}10^6$ OPS/FEATURE
• DATA THROUGHPUT	8-500 MOPS	10-300 MOPS	1-5 MOPS, MLIPS
• PROCESSING REQUIRED	ARITHMETIC, SIMPLE	ARITHMETIC, LOGICAL	FLOATING POINT SYMBOLIC NON-NUMERIC
• CONTROL	SYNCHRONOUS (SIMD)	TOWARD MIMD	ASYNCHRONOUS, MIMD
• COMMUNICATION	FIXED	CAN BE STRUCTURED AND PREDETERMINED	DYNAMIC AND VARIABLE

FUNCTIONAL ANALYSIS SUMMARY
(CONTINUED)

- MIX OF COMPUTATIONS AND CONTROL STRATEGIES
- INCREASING NON-DETERMINISTIC BEHAVIOR
- SHIFT IN POTENTIAL PARALLELISM FROM DATA TO ALGORITHMS
- PERHAPS CONFLICTING ARCHITECTURAL SOLUTIONS?
- ROLE OF COLOR NEEDS TO BE DETERMINED
- IMPACT OF DYNAMIC AND STATIC NATURE OF DATA STRUCTURES TO BE EVALUATED

COMPUTATIONAL CHARACTERISTICS



CONCURRENT PROCESSING ARCHITECTURES

- SPECIAL-PURPOSE PROCESSORS
- WORD-SEQUENTIAL PROCESSORS
- ASSOCIATIVE PROCESSORS
- ARRAY PROCESSORS
- PIPELINE PROCESSORS
- RECONFIGURABLE PROCESSORS
- MULTIPROCESSORS
- DATA FLOW PROCESSORS
- OBJECT-ORIENTED PROCESSORS
- INFERENCE PROCESSORS